

Modulus vs Toughness

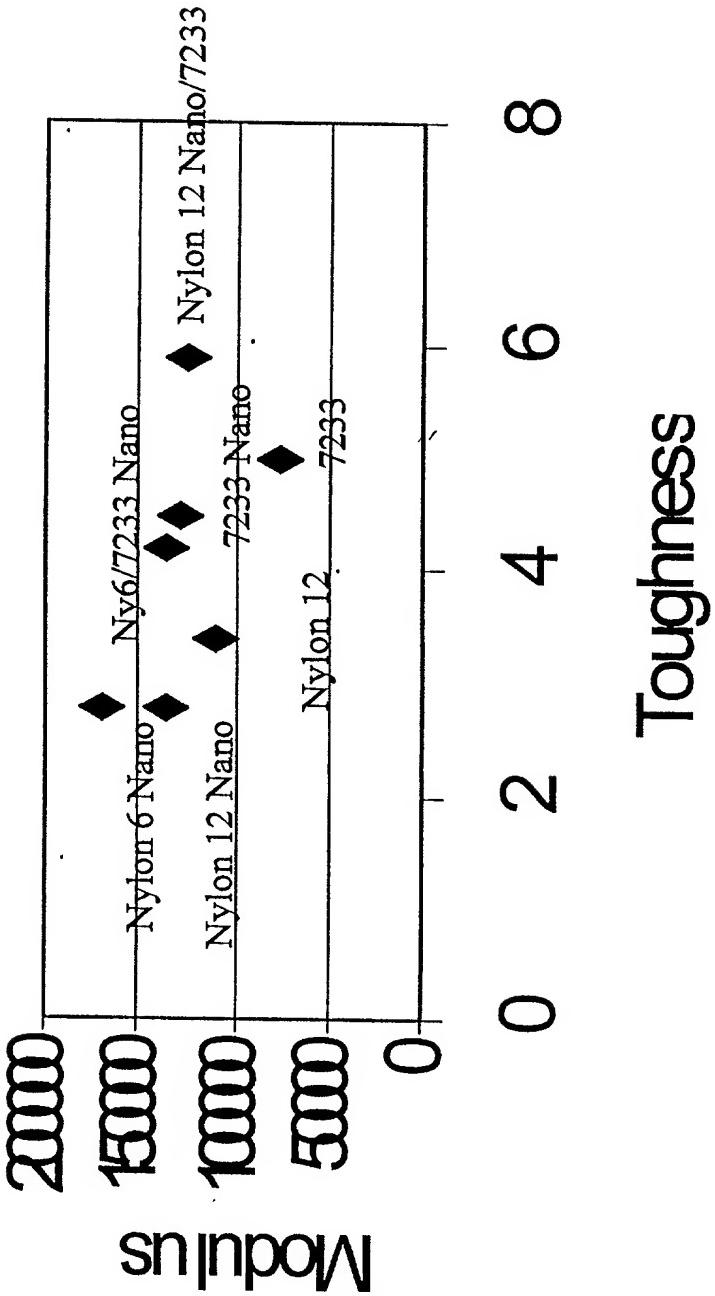


Figure 1

Nylon Nanocomposite Versus Standard Nylon Tubing

Effect of Nanoparticles	
Mechanical Properties	
Durometer (Modulus)	++
Burst Pressure	+
Tensile Strength	+
Tensile Elongation	-
Tear Strength	+
Heat Resistance (HDT)	++
Dimensional Stability	++
Surface Properties	
Dirt Retention	+
Printability	++
Lubricity	+
Barrier Properties	
Gas Barrier	++
Solvent Resistance	+
Aroma Barrier	++
UV Barrier	+

++ Much Improved + Slightly Improved
- Not Improved

Figure 2

Nylon 12, Nylon 12 Nano, Pebax 7233, and Pebax 7233 Nano

Property	ASTM Test Method	Nylon 12 Aesno TL	Nylon 12 Nano 5% I42	Pebax 7233 Nano 5% I42	Pebax 7233 Pebax 7233 Nano 5% I42
Tensile Modulus	D638 (psi) Young	260,000	312,000	134,000	208,000
Tensile Str. @ Break	D638 (psi)	6800	6800	4785	5400
Elongation @ Break	D638 (%)	256	329	458	464
Hardness Shore D	D2240	D74	D78	D70	D72
Melting Pt.	D3418 (deg C)	179	178	172	172
Specific Grav.	D792 (g/cc)	1.02	1.04	1.02	1.03

*Increase of Stiffness and Ductility on Injection Molded Tensile Bars

*I42 is the nanoparticle from Nanocor fully designated I.42.TC

Figure 3

Nylon 12, Nylon 12 Nano, Pebax 7233, and Pebax 7233 Nano 6F Catheter Tubing

Property	ASTM Test Method	Nylon 12 Aesno TL	Nylon 12 Nano 5% I42	Pebax 7233 Nano 5% I42	Pebax 7233	Pebax 7233
Tensile Modulus	D638 (psi) Young	110,000	136,000	75,000	127,000	
Tensile Str. @ Max. load	D638 (psi)	8600	5500	11,000	9000	
Elongation @ Break	D638 (%)	396	500	456	502	
Tens strength x Elong @ break	(x 1,000,000)	3.4	2.8	5.0	4.5	
Melting Pt.	D3418 (deg C)	179	178	172	172	
Specific Grav.	D792 (g/cc)	1.02	1.04	1.02	1.03	
Dimensional Stability	--	--	++	--	--	++
Dirt Retention	--	+	-	-	+	+

* Increased Stiffness and Ductility Plus With Dimensional Stability and Improved Surface
 * Control of modulus from 75,000 to 136,000 all at similar melting points

Figure 4

Nylon 11, Nylon 11 Nano, Pebax 2533, and Pebax 2533 Nano

6F Catheter Tubing

Property	ASTM Test Method	Nylon 11 Besno TL	Nylon 11 Nano 5% I42	Pebax 2533	Pebax 2533 Nano 5% I42
Tensile Modulus	D638 (psi) Young	112,000	134,000	<5000	<5000
Tensile Str. @ Max. load	D638 (psi)	12,600	7400	--	--
Elongation @ Break	D638 (%)	462	462	>500	>500
Tens strength x Elong @ break	(x 1,000,000)	5.8	3.4	--	--
Melting Pt.	D3418 (deg C)	190	190	--	--
Specific Grav.	D792 (g/cc)	1.03	1.05	1.01	1.02
Dimensional Stability	--	--	--	--	+
Dirt Retention	--	--	--	--	+

Figure 5

Nylon 12 Nano, Pebax 7233, Nylon 12 Nano/7233, and Pebax 7233 Nano 6F Catheter Tubing

Property	ASTM Test Method	Nylon 12 Nano 5% I42	Pebax 7233	Nylon 12 Nano/ Pebax 7233	Pebax 7233 Nano 5% I42
Tensile Modulus	D638 (psi) Young	136,000	75,000	124,000	127,000
Tensile Str. @ Max. load	D638 (psi)	5600	11,000	12,000	9000
Elongation @ Break	D638 (%)	500	456	494	502
Tens strength x Elong @ break	(x1,000,000)	2.8	5.0	5.9	4.5
Melting Pt.	D3418 (deg C)	178	172	--	172
Specific Grav.	D792 (g/cc)	1.04	1.02	1.03	1.03
Dimensional Stability		++	--	++	++
Dirt Retention		++	--	++	++

*Nylon 12 Nano/Pebax 7233 is a 50/50 blend with total nanoparticles concentration of 2.5%

Figure 6

Nylon 12 Nano, Nylon 11 Nano, Nylon 12 Nano/7233, and Nylon 11 Nano/7233 6F Catheter Tubing

Property	ASTM Test Method	Nylon 12 Nano 5% 142	Nylon 11 Nano 5% 142	Nylon 12 Nano/ Pebax 7233	Nylon 11 Nano/ Pebax 7233
Tensile Modulus	D638 (psi) Young	136,000	134,000	124,000	113,000
Tensile Str. @ Max. load	D638 (psi)	5600	7400	12,000	5100
Elongation @ Break	D638 (%)	500	462	494	251
Tens strength x Elong @ break	(x1,000,000)	2.8	3.4	5.9	1.3
Melting Pt.	D3418 (deg C)	178	190	--	--
Specific Grav.	D792 (g/cc)	1.04	1.05	1.03	1.04
Dimensional Stability		++	++	++	++
Dirt Retention		++	++	++	++

*The 50/50 blend of Nylon 12 Nano/Pebax 7233 was superior to the corresponding 50/50 blend of Nylon 11 Nano/Pebax 7233

Figure 7

Nylon 12 Nano, Nylon 6 Nano, Nylon 6 Nano/7233, and Nylon 6 Nano/2533 - 6F Catheter Tubing

Property	ASTM Test Method	Nylon 12 Nano 5% I42 Nano XA2908	Nylon 6 Pebax 7233	Nylon 6 Nano/Nylon 6 Nano Pebax 2533	*Nylon 6 Nano/ Pebax 7233 Nano
Tensile Modulus	D638 (psi) Young	136,000	171,000	136,000	94,000
Tensile Str. @ Max. load	D638 (psi)	5600	9900	10,000	10,000
Elongation @ Break	D638 (%)	500	287	415	600
Tens strength x Elong @ break	(x1,000,000)	2.8	2.8	4.2	6.0
Melting Pt.	D3418 (deg C)	178	217, 274	--	--
Specific Grav.	D792 (g/cc)	1.04	1.12	1.06	1.06
Dimensional Stability	++	--	--	--	--

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Dirt Retention
Nylon 6 Nano XA2908 was obtained from Honeywell International at a reported nanoparticle level of 2.0%. The addition of Pebax to XA2908 improved processability and ductility.
*for tubing 0.022" to 0.017"

Figure 8